throw, resulting in a talus or fan on the lee side, (2) by percolation, especially where there is large tidal difference, or (3) by stream scour on the lee side. *Suaeda fruticosa* is able to colonize upward growing shingle, quite as *Psamma* may colonize an upward growing dune; *Suaeda* is an especially good pioneer, because of its halophytic proclivities. Later stages, as shingle growth decreases, are characterized by mat plants such as *Silene maritima* and *Convolvulus Soldanella*. A plant of the latter increased in area within four years from 9 to 525 square feet.

An interesting chapter deals with the reclamation of salt marshes. It is OLIVER's view that a marsh would not fill alone by silting, by reason of alternate filling and cutting. Reclamation may be brought about naturally by coastal elevation or by the building up of a barrier dune, or it may be brought about by artificial agencies. A remarkably effective plant reclaimer of halophytic shores is *Spartina Townsendii*, a supposed natural hybrid of *S. stricta* and *S. alterniflora*. This species was first noted at Southampton in 1870, and now covers thousands of acres. In 1895 it appeared at Bayonne, on the Bay of Biscay. It is interesting to note that these two areas are the only ones known where the areas of the supposed parent species overlap. —H. C. COWLES.

NOTES FOR STUDENTS

Root systems.—Since the notable work of CANNON in 1911 on the roots of desert plants, nothing has contributed so much to our knowledge of subterranean plant organs as the recent publication by WEAVER,[2] in which he has described the root systems of some 140 species of shrubs and herbs from the prairies of Nebraska and Washington, the plains and sand hills of Colorado, and some gravel slide and forest communities of the Rocky Mountains of Colorado. For each of the habitats under investigation many data regarding such environmental conditions as rainfall, evaporation, and soil moisture are given. These data and the abundance of illustrative drawings and photographs of excavated root systems are among the most valuable features of the report.

In the Nebraska prairie there is a striking individuality in the root systems, and a grouping of the roots into more or less definite absorbing layers, thus reducing competition and permitting the growth of a larger number of species. The deeper rooted species comprise 55 per cent of the 33 species examined, and extend beyond a depth of 5 feet, some reaching as much as 20 feet below the surface, many of them having few or no absorbing roots in the first few feet of soil. The majority of the deeply rooted species are dicotyledons; but it is notable that the group also includes three dominant grasses, *Panicum virgatum*, *Andropogon furcatus*, and *Agropyron repens*. In contrast

[2] WEAVER, J. E., The ecological relations of roots. Carnegie Inst. Wash. Publ. 286. pp. vii+128. *pls. 33. figs. 58.* 1919.

with this group, all plants with roots confined to the upper 2 feet of the soil are grasses, and include such species as *Koeleria cristata*, *Stipa spartea*, *Elymus canadensis*, and *Distichlis spicata*.

Such root systems are to be related to the deep, mellow, loess soil with high water-holding capacity and moist subsoil. Here the data of WEAVER correspond well with those of ALWAY[3] for moisture conditions, although the former finds a much deeper root development than that assumed by the latter. In the upper 4 or 5 feet there is usually at midsummer a reduction of the water supply to a point below the wilting coefficient, these data corresponding with those of the reviewer for the grasslands of the Chicago region.[4]

The climatic conditions of the prairies of southeastern Washington are shown to be more severe than those of Nebraska, not only because of a smaller annual precipitation, but also because only one-third of this rainfall comes during the growing season. As a part of the response, the early flowering grasses predominate, and many of these, such as *Koeleria cristata*, *Poa Sandbergi*, and *Festuca ovina* have their roots confined to the upper 18 inches of soil. There remain, however, some grasses and many dicotyledons that are decidedly deep rooted.

Some data also are given for a "chaparral" community transitional from the prairie to the forest, and dominated by species of *Symphoricarpos*, *Rhus*, *Corylus*, and *Rosa*. The designation is unfortunate, for the best usage would limit the term "chaparral" to an evergreen scrub like that occurring on the Pacific Coast of California.

In comparison with the root systems of the prairies, those of the plains are characterized by a larger percentage of moderately deep rooted species, fewer very deeply rooted plants, and by a more extensive system of surface absorbing and wide spreading laterals. SHANTZ[5] reported that at Akron, Colorado, almost the entire root system of all the grasses is limited to the 18 surface inches. The conditions are evidently different near Colorado Springs, for there WEAVER reports one grass only, *Koeleria cristata*, with roots confined to the surface 2 feet. Grouping into layers is again evident; the most distinctive feature of the plains species, in addition to spreading laterals, is the moderate penetration of the deep rooted species. This is doubtless due, as indicated by both WEAVER and ALWAY (*loc. cit.*), to the comparative impenetrability of the extremely dry subsoil.

The sand hill community exhibits in a still more striking manner the development of a profusion of widely spreading laterals in the upper 2 or

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[3] ALWAY, F. J., *et al.*, Relation of minimum moisture content of subsoil of prairies to hygroscopic coefficient. BOT. GAZ. 67:185–207. 1919.

[4] BOT. GAZ. 58:193–234. 1914.

[5] SHANTZ, H. L., Natural vegetation as an indicator of the capabilities of land for crop production in the great plains area. U.S. Dept. Agric., Bur. Pl. Ind. Bull. 201. pp. 100. *pls. 6. figs. 23.* 1911.

3 feet of soil. This is true even of the deep rooted species, and is doubtless to be related to distribution of soil moisture. It is notable that MARKLE[6] found a similarly abundant development of even more superficial laterals in the very arid conditions in New Mexico. MARKLE also described and figured a considerable variety of systems, and found rather definite layers of penetration lessening competition for the scarce water supply.

In the succession from the gravel slide with coarse soil to the forest rich in humus, the Colorado Rocky Mountains afford an interesting series. WEAVER finds decidedly superficial systems, both in the very sparsely populated gravel and in the undergrowth of the forest, with the moisture distribution the controlling factor in each case. The intermediate half gravel slide, with its surface more than half occupied with plants, curiously enough has more deeply rooted plants than the associations preceding or succeeding it.

A comparison of species occurring in two or more different habitats shows that of 10 species examined, 7 exhibit changes in root habit in response to the changed environment, while 3 remain quite constant. Such studies of the response of root systems to environment have attracted the attention of other workers. WATERMAN[7] finds roots developing under dune conditions somewhat responsive to organic remains in the sand, although usually adhering rigidly to their specific inherited form. Such rigidity was found by PULLING[8] in the shallow root systems of *Picea mariana*, *Larix laricina*, and *Betula alba papyrifera*, as well as in the more deeply rooted *Pinus Strobus* and *P. Banksiana;* while both the shallow rooted *Picea canadensis* and the deep rooted *Populus balsamifera* exhibited considerable plasticity.

CANNON[9] believes that the roots of deeper penetration are less responsive to changes in aeration and temperature than those of more superficial habit, basing his conclusion upon the study of *Pistacia atlantica* and *Prosopis velutina* of the former class, and *Opuntia versicolor* and *O. discata* of the latter class. The individuality of such responses is further shown by the studies of CANNON and FREE,[10] proving that while certain plants like *Opuntia* stop root growth with a soil atmosphere of 50 to 75 per cent carbon dioxide, others, like *Prosopis*, continue growth as long as 2 per cent of oxygen is

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[6] MARKLE, M. S., Root systems of certain desert plants. BOT. GAZ. **64**:177–205. *figs. 33.* 1917.

[7] WATERMAN, W. G., Development of root systems under dune conditions. BOT. GAZ. **68**:22–53. *figs. 17.* 1919.

[8] PULLING, H. E., Root habit and plant distribution in the far north. Plant World **21**:223–233. *fig. 1.* 1918.

[9] CANNON, W. A., Modifications of root habits by experimental means. Carnegie Inst. Wash. Yearbook **17**:83–85. 1919.

[10] CANNON, W. A., and FREE, E. E., The ecological significance of soil aeration. Science N.S. **45**:178–180. 1917.

present. They also showed that while the roots of *Coleus blumei* and *Heliotropium peruvianum* show injury in 3 days by an addition of 25 per cent nitrogen to the soil atmosphere, *Nerium oleander* is unharmed by 50 per cent of nitrogen, and the roots of *Salix* (*nigra?*) grow freely in pure nitrogen. Similar results were obtained by the use of helium instead of nitrogen as a diluting gas.

More recently BERGMAN[11] has found similar differences of response in the roots of land and swamp plants, the dead roots in the former often being replaced by others near the surface of the water, showing lack of aeration to be one of the most important factors involved. Several experiments serve to give emphasis to this fact. He found that land plants with submerged roots soon show pronounced wilting, the wilting being less marked when the submergence is in aerated water, and a reduction in transpiration preceding wilting. This is taken to indicate that absorption is reduced below the amount demanded by transpiration. When aeration is provided, the use of swamp water for submergence or watering gives no other harmful results than those obtained by the use of tap water or nutrient solutions. The oxygen content of swamp water in nature was found to be large in the open lakes examined, but to show decided decrease through the *Carex* stages to the *Chamaedaphne-Andromeda* and *Larix-Picea* stages. This leads to the conclusion that the mingling of hydrophytes, mesophtyes, and xerophytes in swamps is due to local differences in habitat, such as water level and aeration, affecting the rate of absorption and its ratio to transpiration; hence ecesis in swamps can occur only when the oxygen requirements of the species are satisfied.

These citations show that considerable descriptive matter has added materially to our knowledge of root systems, and that the few physiological investigations of these organs have pointed to wide diversity in the responses of individual species to changes in their environment.—GEO. D. FULLER.

Alpine vegetation of the central Andes.—HAUMAN[12] has recently described a scanty alpine vegetation found on the Andes between 31 and 37° south latitude, at elevations ranging from 2000 to 42,000 m. This region possesses many peaks above 6000 m. high, the highest and best known being Aconcagua, with an altitude of 7020 m. These mountains are snowcapped and possess a good development of glaciers, from which flow tortuous and variable streams, furnishing almost the entire water supply for the sparse vegetation, since the growing season in these mountains is almost entirely without rain. The temperature records are imperfect, but an important factor is the light frosts,

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[11] BERGMAN, H. F., The relation of aeration to the growth and activity of roots and its influence on the ecesis of plants in swamps. Ann. Botany **34**:13–33. *fig. 3*. 1920.

[12] HAUMAN, LUCIEN, La végétation des hautes cordillères de Mendoza (République Argentine). Anales Soc. Cien. Argentina **86**:121–188. *pls. 5–22. figs. 7.* 1918.